Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Updating FM Broadcast Radio Service Directional Antenna Performance Verification	)	MB Docket No. 21-422
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COMMENTS OF ELECTRONICS RESEARCH, INC.

Contents

I. Introduction and Summary

The Federal Communications Commission has opened this proceeding to consider relaxing the requirement that directional FM antennas for full-service and low-power FM stations submit measured azimuth pattern data, taken at either full-scale or with a fractional scale model. Electronics Research, Inc. (ERI) is a manufacturer of broadcast transmission equipment that has been involved in the production of FM antennas and other transmission system components from the early days of the service. ERI has serious concerns regarding this proposal and believes these changes would be harmful to this essential audio service which touches 88% of the adult population of the US every week[1]. ERI's concerns are based on the following:

1. The FM Broadcast Band has a history of changes and additions to the types of services authorized, the power levels at which they have been allowed to operate, and the criteria used to site new facilities through modifications to the table of FM allotments. The result has been an ever-increasing number of authorized facilities and a continuing impairment of fringe coverage.
2. The proposed changes would allow computer studies to be used to confirm compliance with authorized facilities with no verification that the performance of the computer simulation is accurate and correct.
3. The changes proposed are a relaxation of the rules applied to full-service FM stations. These facilities do not have an obligation to immediately cease operation if they cause interference to other full-service FM stations, as is the case for secondary services, FM translators, FM Boosters, and Low Power FM stations.

The ERI filing includes details and testing to support our position that approving these changes to the FCC rules would be detrimental to the public and to FM broadcast services. The proceeding Report and Order amending the Commission's Rules Regarding FM Translator interference included the statement:

> "balancing the interests of the various services involved is particularly critical given the present-day saturation of the FM spectrum in many markets. Because of the maturity of the FM service, we must not only balance the needs of translator, low power FM and full-service licensees, but also take into account concerns such as the overall noise floor and technical integrity of the FM band."[2]

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[1] Nielsen Total Audience Report June 2021.
[2] FCC MB Docket No. 18-119, Report and Order adopted May 9, 2021, paragraph 4.

ERI believes those same interests and concerns should be part of this proceeding. The modifications of the Part 74 rules done under MB Docket 18-119 allowed FM translator interference complaints to be resolved quickly with a change in FM channel to any other available same band FM channel, standardized the information that was required to be compiled and submitted by any station to support an interference complaint, established complaint resolution procedures, and set the outer contour limit for the affected station within which interference complaints would be considered actionable. These rules were established to resolve interference complaints with FM translators, a secondary service that is licensed on the basis that it will cease operation if it interferes with another licensed FM facility. ERI believes the changes proposed in this proceeding have the potential to "create protracted and contentious interference disputes[3]" as they would involve full-service FM stations that are licensed as a primary service.

II. The FM Broadcast Band has a History of Station Growth and Increasing Congestion

Since the current FM band was first allocated to provide high fidelity audio services in 1945[4], the FM band has been subject to increasing congestion, creating the potential of interference between FM broadcast facilities, which can negatively impact service to the public. When the Commission rules were significantly overhauled in 1963, directional FM antennas were first included but only for "the purpose of improving service and not as an assignment tool.[5]." In addition to allowing the use of directional FM antennas, this rule change created the Class C FM facility, authorized for up to 100 kW Effective Radiated Power (ERP) for FM

[3] FCC MB Docket No. 18-119, Report and Order adopted May 9, 2021, paragraph 1.
[4] FCC Docket No. 6651 dated June 27, 1945.
[5] FCC 62-866 paragraph 86.

Broadcast Zone II and also allowed Class B facilities to increase ERP from 10 kW to 50 kW with no change in spacing between co-channel, first, second, and third adjacent channel facilities.

In a subsequent rulemaking, the Commission relaxed its position on using directional FM antennas as an allocation tool and added section 73.215 to the FCC rules to allow directional FM antennas to be used to provide Contour protection and allowed for new FM stations "short spaced" to existing facilities and allocations to allow more FM radio stations to be built and enhance the variety of audio services available to the public[6]. This change to allow new FM broadcast facilities to be built short-spaced to existing stations followed the FCC rules changes initiated by the FCC Docket 80-90[7] proceeding to increase the number of Commercial FM Radio Station facility allocations. The changes allowed most US Class A FM stations to double their effective radiated power from 3 kW to 6 kW and operate on any available FM channel instead of limiting them to 20 assigned FM channels. The proceeding created 684 new FM allocations through an omnibus proceeding and modified the Commission's FM rules to add the additional facilities to the FM Table of Allotments.

In addition to the changes to the full-service FM rules, which allowed for the number of full-service FM radio stations to grow from 2,306 in 1968 to 10,880 at the end of 2021,[8] there have been new secondary services authorized to provide FCC licensed audio services in the FM broadcast band those include:

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[6] FCC 88-406, FM Broadcast Service; Use of Directional FM Antennas in Making Short-Spaced Station Assignments.
[7] FCC 84-65 Modification of FM Broadcast Station Rules to Increase the Availability of Commercial FM Broadcast Assignments.
[8] Source FCC Broadcast Station Totals.xls, DOC-342889A1, DOC-348570A1, DOC-355826A1, DOC-361678A1, DOC-369041A1, and DA-22-2A1.

1. In 1970 the Commission authorized FM Translators and on-frequency FM Boosters to provide service in white areas without local FM audio services and to provide fill-in coverage to overcome terrain shadowing.
2. In 2009 the Commission's revitalization efforts for the AM broadcast band included allowing AM radio stations to add FM translators to simulcast their AM programming, including overnight for AM stations that were limited to daytime only operation.
3. In 2011 the Commission authorized and created the Low Power FM (LPFM) class of non-commercial broadcast stations to provide service to small communities. The creation of this service also included implementation of the requirements of the Local Community Radio Act of 2010, which required the FCC to modify its rules to eliminate third-adjacent minimum distance separation requirements between low-power FM stations; and full-service FM stations, FM translator stations, and FM booster stations.[9]

All of these authorizations of additional services in the FM band have reduced fringe area coverage for full-service FM stations and, in some cases, have caused interference that has resulted in the loss of service. In the proceeding (MB Docket No. 18-119) Regarding FM Translator Interference, the Commission accepted the empirical evidence presented that showed a substantial portion of an FM facility's audience comes from outside its 54 dBu protected contour. In its Amendment of Part 74 of the Commission established the 45 dBu contour of a full-power FM, LPFM, FM translator, or FM booster signal strength as the limit to which it may claim interference[10].

[9] 27 FCC Rcd 3315 MM Docket 99-25 para 15-46
[10] Report and Order, 34 FCC Rcd at 3475-81, paras. 36-48.

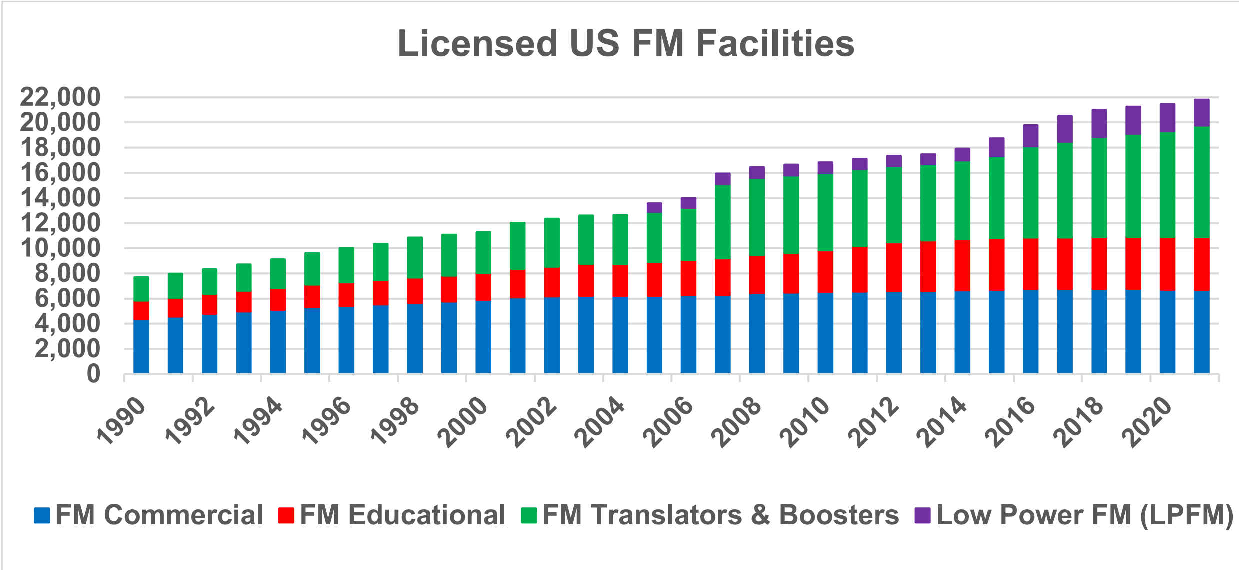

Figure 1 Licensed FM Broadcast Facility growth 1990 through 2021[11].

III. The Commission Requires Verification of the Accuracy of Computer Models for Other Services

The Notice of Proposed Rulemaking cites the Commission allowing the use of computer models to demonstrate compliance with the rules and places emphasis on the changes made to the AM Directional Antenna rules, allowing "method of moments" verification to confirm the compliance of directional antenna systems with a computer model, instead of requiring field measurements[12]. There is no doubt that this rule change represents a significant benefit to AM broadcast station licensees and was the result of a lengthy proceeding. Title 47 CFR §73.151(c) of the rules establishes the requirements for computer modeling and sample system verification. The regulations include provisions that serve to verify that the predictions of the computer

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[11] Source FCC Broadcast Station Totals.xls, DOC-342889A1, DOC-348570A1, DOC-355826A1, DOC-361678A1, DOC-369041A1, and DA-22-2A1. Count of all Commercial and Educational Full-Service FM Stations, FM Translators and Boosters, and Low Power FM Stations from 1990 through 2021. Taken from the December 31 FCC Broadcast Station Totals Reports. Except for 1990 and 200 when data from the report for September 30 was used due to a computer changeover by the FCC.

[12] FCC 21-117, MB Docket No. 21-422, para 7.

models are accurately portraying the actual performance of the directional antenna array, including:

1. Limiting the use of computer modeling and sample system verification to only those AM antenna arrays using series fed elements.
2. The orientation and distances between the individual antenna towers in the array must be confirmed and certified after construction by a land surveyor licensed or registered in the state or territory where the antenna system is located.
3. A complete description of the sampling system and the results of the measurements required to verify the computer model must be submitted with the facility application for a license.
4. The measured antenna monitor sample indications and the measured matrix impedances of each tower, those calculated by the method of moments program, must agree within the tolerances defined in 47 CFR §73.151(c) (2) (ii).
5. The application for an initial license for an AM directional antenna system based on computer modeling must include reference field strength measurements on each radial corresponding to a pattern minimum and maximum. These measured values must match the computer simulation.

In comments filed by one of the original petitioners that initiated this Rulemaking Proceeding, Shively Labs stated that "If there are several ways to produce inaccurate results from a full or scaled range measured pattern, as suggested in the petition, then there are dozens of ways with computer-generated models. At least in the discovery phase, a validation step will ensure the computer model is correct."[13] While the comments affirmed Shively's continued

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[13] Shively Labs Comments on NPRM FCC 21-117 Docket 21-422 Directional Antenna Pattern Verification Update ECFS posting on January 3, 2022.

support of the petition to modify the FM directional antenna rules, the comments do raise concern regarding the acceptance of computer-generated calculations without verification through modeling at full or fractional scale.

As a matter of practice, the major suppliers of television antennas have always measured the azimuth (parallel to the earth) pattern and the elevation (perpendicular to the earth) pattern of television antennas as the most critical item of credibility as it is used by both manufacturers and broadcasters for influencing or making an antenna purchasing decision.

The azimuth pattern verification is critical for determining coverage area and meeting FCC and other restrictions for the protection of other facilities from interference. In the early days of television, the standard for measurement was a full-scale test range, which often occupied significant physical space, particularly if low-band VHF (RF Channels 2 through 6) television antennas needed to be measured. In 1978 Andrew Corporation[14] introduced the TRASAR® UHF television antenna, which used Anechoic Chamber modeling to develop and for the production testing of the azimuth pattern of antennas in the manufacturing process. The anechoic chamber is designed with absorbing material that covers the walls, ceiling, and floor to prevent any unwanted reflections during the measurement procedure[15]. The anechoic chamber is a controlled measurement environment. It aims to represent the free space condition of the design criteria because it minimizes reflections and, at the same time, allows direct measurement of the azimuth pattern. It is not subject to the dynamic environmental influences that affect measurements on a far-field test range, reflections from buildings, vegetation, seasonal changes,

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[14] Electronics Research, Inc. acquired the assets of Andrew Corporation's Broadcast Products Business Unit in 2003 and relocated the engineering and manufacturing operations for those products to its expanded facility near Evansville, Indiana.
[15] Kummer, W.H., ed., IEEE Standard Test Procedures for Antennas – IEEE Std 149-1979, John Wiley & Sons, Inc., New York, 1979

rain, snow, or ice. This assures both very accurate measurement results and repeatability of the results at any time. When Andrew Corporation relocated the manufacturing location for TRASAR® television antennas to its headquarters in Orland Park, Illinois, the company built a larger anechoic chamber to add the capability to perform azimuth pattern measurements for high band VHF (RF Channels 7 through 13) television antennas as well.

The elevation pattern measurement of a television antenna is as important as azimuth pattern measurement as it determines the antenna gain, side lobes, and verification of the electrical beam tilt of the array, which are all critically important to delivering sufficient signal strength to the entire area to be served. To determine the elevation pattern of the antenna requires that the entire array be assembled and that the phase and amplitude distribution across the aperture be measured. Because reflections and extraneous signals can cause significant error in this measurement, ideally, the antenna should be placed inside an anechoic chamber and the elevation pattern measured in the same manner as the azimuth pattern. However, the physical size and cost of such a structure prohibit this in the VHF and UHF television bands. An alternate method of measurement was developed to simulate the "free space" condition of the anechoic chamber. This nearfield method uses an isolated probe to measure the slot excitation (amplitude and phase) of each slot in the array. The product of the array factor and the measured pattern of the one-bay element produces the calculated elevation pattern. The measured data and pattern are compared with the design data for conformance to design specifications. There are two major advantages of this measurement technique. Because the measurements are made in the nearfield, the effects of reflections and other unwanted signals are greatly reduced. Also, because the elevation pattern specifications are based on a particular phase and amplitude distribution across the aperture, a direct comparison between predicted and measured patterns and distributions is possible.

These methods of azimuth and elevation pattern measurement have been employed by the primary television antenna manufacturers since the late 1980's. They are proven methods for gathering accurate representations of antenna patterns and performance. While §73.685(f) of the FCC rules did not specifically require the submission of measured azimuth and elevation patterns, ERI and other manufacturers have been making those measurements and including the data in published literature, product test reports, and in the documentation shipped to the customer, along with the antennas purchased. The statement included in Dielectric's comments filed into the record of this proceeding, "Accumulated in this report are VHF and UHF Repack antennas that were designed exclusively through virtual simulation"[16] was the first time ERI became aware that Dielectric was no longer performing measurements to confirm the actual azimuth pattern performance of the UHF and VHF television antennas it manufactures.

IV. The Directional FM Antenna Example in the Proponents Petition is not Representative of the Majority of Directional FM Antennas Proposed or Licensed

The Joint Petition for Rulemaking – Computational Modeling of FM Directional Antennas filed by Dielectric, LLC, Educational Media Foundation, Jampro Antennas, Inc., Radio Frequency Systems, and Shively Labs included only a single example of a directional FM antenna to compare a fractional scale model to a simulation using Ansys HFSS software[17]. The antenna is identified as a directional FM antenna built for WHEM (FM), licensed to Eau Claire,

[16] Dielectric Comments on FM Antenna Modeling w-Software NPRM MB Docket 21-422 – Final, page 59 ECFS posting January 3, 2022.
[17] FCC ID 1061557929592. Proceeding INBOX-1.401, The Joint Petition for Rulemaking – Computational Modeling of FM Directional Antennas filed June 15, 2021, by Dielectric, LLC, Educational Media Foundation, Jampro Antennas, Inc., Radio Frequency Systems, and Shively Labs, Section III, Subheading E, pages 17 – 23.

Wisconsin. The antenna is a single bay FM antenna mounted to a 10-inch OD pole; this is not representative of most directional FM antenna systems in use.

Figure 2 WNFN (FM), Franklin, TN (FCC ID 29862) ERI Model SHP-4AE-DA-HW Directional FM Antenna mounted on a 7.5-foot face tower with conduits for pattern shaping and ladder and television rigid transmission line through the antenna mounting aperture.

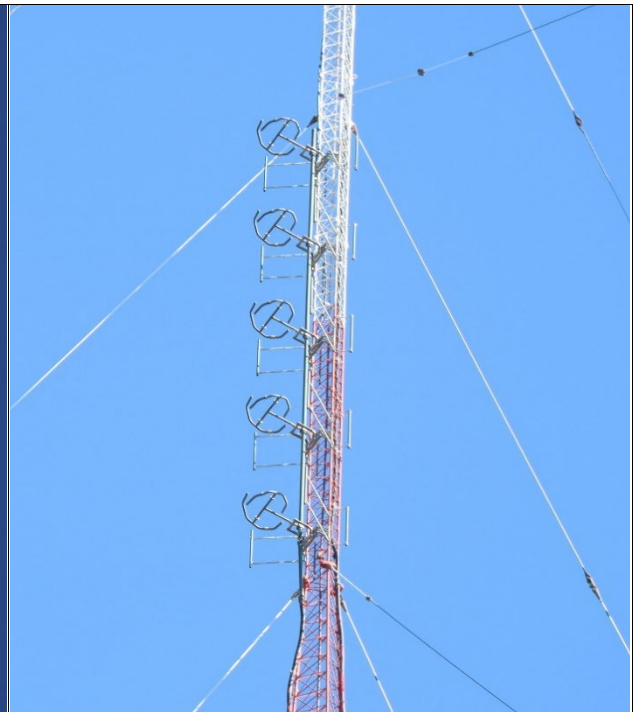

Figure 3 WMOT (FM), Murfreesboro, TN (FCC ID 41997) ERI Model LP-5E-DA Directional FM Antenna mounted on a 24-inch face tower. The guy wires are insulated through the antenna aperture to minimize reflections. The other transmission line feeds an FM antenna mounted higher on the tower.

The vast majority of the proposals generated and orders filled by ERI for directional FM antennas are for multi-bay arrays mounted on lattice structures below the tower top of steel. The development of a computer model on this type of structure that will accurately reflect the azimuth and depth of the nulls required to prevent interference to other facilities is not a simple process and requires significant effort to build an accurate representation of the antenna, the pattern shaping directors, antenna brackets, transmission lines, ladders, conduits, and the support structure itself. Further, the electromagnetic simulation software is known to have shortcomings in predicting the depth and angle of nulls, which are critical in determining the protection a directional FM antenna provides to short-spaced co-channel and adjacent channel FM facilities.

Dielectric's comments, which included HFSS simulated patterns and corroborating drone measurements, are primarily of UHF television antennas, many of which are top-mounted and as such have little similarity to the directional FM antenna types that are the subject of this proceeding. ERI disagrees with the conclusions stated on Appendix A, page 54 of this filing, particularly the statement that "HFSS simulation can be applied to all frequencies, but since lower FM frequencies will be less susceptible to manufacturing or tower data tolerances, the simulations will deliver more accurate predictions of patterns."[18] ERI's experience has shown that computer predictions of tower scatterings at FM frequencies are less accurate than scattering studies made for side-mounted UHF television antennas.

At ERI, all of our UHF and High Band VHF television antennas, whether they are horizontally, elliptically, or circularly polarized, have their azimuth patterns measured in our calibrated far-field anechoic chamber with a quiet zone of 20 feet by 20 feet. The antennas are designed to have a constant geometry in elevation as well as a constant coupling value per radiating element. The vertical and horizontal parameters measured in the anechoic chamber are used to confirm elevation and azimuth patterns once the complete antenna is manufactured.

For more than forty years, ERI has utilized proprietary engineering software and commercially available software, including HFSS, among others, to assist in the design and development of our antennas. It is our documented experience that HFSS predicts azimuth patterns with an error between one and two decibels for symmetrical non-directional patterns, an error greater than 3.6 dB for -8.0 dB nulls. This error doubles when the nulls exceed -16 dB.

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[18] Dielectric Comments on FM Antenna Modeling w-Software NPRM MB Docket 21-422 – Final, Appendix A ECFS posting January 3, 2022.

Our customers have shared antenna drone measurements performed by reputable firms that provide this service, all with several years of experience. ERI considers this to be a novel application to the measurement of antennas already installed on towers. The reports submitted of symmetrical azimuth antenna patterns present a deviation from our anechoic chamber measurements from one to 3.5 dB. The elevation pattern drone measurements' accuracy is not reliable. The error is close to 3 dB on the main beam and exceeds by more than 5 dB on the side lobes between 0 and 10-degrees of elevation.

The biggest problem ERI has found with using HFSS to predict pattern coverage is the software's ability to predict the pattern of the FM antenna elements in free space. After discussions with ERI's Ansys Partner Simutech, in December 2021, the company provides service support to ERI for HFSS; they agreed that the region of the predicted pattern that would have the largest errors would be in the nulls of the pattern, which is where the FCC protected areas are defined and most critical.

V. The Petitioners Characterizations of the Measurement Errors in Range Testing are not Accurate

The Joint Petition presents antenna range measurements as a process that is susceptible to errors in terms of the models of the antennas and the support structures used and in the setup, alignment, and calibration of the test range components themselves.[19] Included as Appendix A to these comments are details of the calibration tests performed on ERI's far-field, full-scale FM antenna test range which demonstrate a range error of less than ±1.13 dB of the measured results of the horizontally polarized signal component of an FM antenna under test and less than ±0.72

[19] FCC ID 1061557929592. Proceeding INBOX-1.401, The Joint Petition for Rulemaking – Computational Modeling of FM Directional Antennas filed June 15, 2021, by Dielectric, LLC, Educational Media Foundation, Jampro Antennas, Inc., Radio Frequency Systems, and Shively Labs, Section III, Subheading A, pages 13 – 14 and Subheading D pages 16 and 17.

dB for the vertically polarized pattern. ERI submits that this low level of range error debunks the notion that the antenna test ranges cannot be built and operated in a manner that provides measured results that are equal to or superior to software simulation.

Appendix B of this filing includes a report demonstrating the accuracy of pattern measurements of ERI's VHF antenna test range with arrays using two and four-bay arrays and provides demonstrated proof that the range measurements of partial arrays and the measured performance of the entire array are both accurate portrayals of the FM antenna under test.

Respectfully submitted,

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January 19, 2022

Appendix A Calibration Tests for Range Error Measurements

The purpose of the tests was to display the effects of the primary specular reflection (ground bounce) on far-field ground reflection range measurements. The tests were performed on the south ERI VHF antenna range.

Pattern measurements were made on a sixty-acre antenna pattern range that is owned and operated by Electronics Research, Inc. The tests were performed under the direction of Thomas B. Silliman, president of Electronics Research, Inc. Mr. Silliman has a Bachelor of Electrical Engineering and a Master of Electrical Engineering degree from Cornell University and is a registered professional engineer in the states of Indiana, Maryland, and Minnesota.

Description of Test Procedure

The test antenna was an ERI model LPX-1E configuration. The antenna was tested on a fiberglass support tower to avoid pattern distortion from the support structure. All tests were performed on a frequency of 98.0 megahertz.

Measurements were performed with the test antenna placed at three horizontal distances from the center of the turntable. The first being the center of the LPX element centered directly above the center of the turntable. The second, with the AUT centered 30-inches from the center of the tabletop, and the third with the LPX element centered at 63.5-inches from the turntable center.

The fiberglass structure was erected vertically on a turntable mounted on a non-metallic building with the antenna centered vertically on the structure, making the center of radiation of the test approximately 22 feet above the ground. The turntable is equipped with a motor drive and a US Digital angle position indicator. The resolution of this angle position indicator is one-hundredth of a degree.

The antenna under test was operated in the transmitting mode and fed from a HP8657D signal generator. The frequency of the signal source was set at 98 MHz and was constantly monitored by a Rohde & Schwarz ESVD measuring receiver.

A broadband horizontal and vertical dipole system, located approximately 628 feet from the test antenna, was used to receive the emitted test signals. The dipole system was mounted at the same height above terrain as the center of the antenna under test.

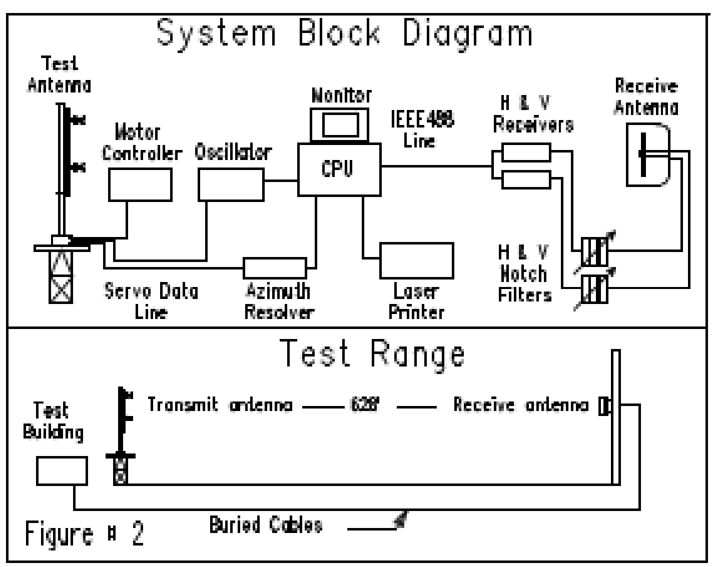

Figure # 2

The signals received by the dipole system were fed to the test building by way of two buried Heliax cables to the measuring receiver. This data was interfaced to a laser jet printer by means of a computer system. Relative field strength was plotted as a function of azimuth.

The measurements were performed by rotating the test antenna in a counterclockwise direction and plotting the received signal on polar coordinated graph paper in a clockwise direction. Both horizontal and vertical components were recorded separately.

Respectfully submitted,

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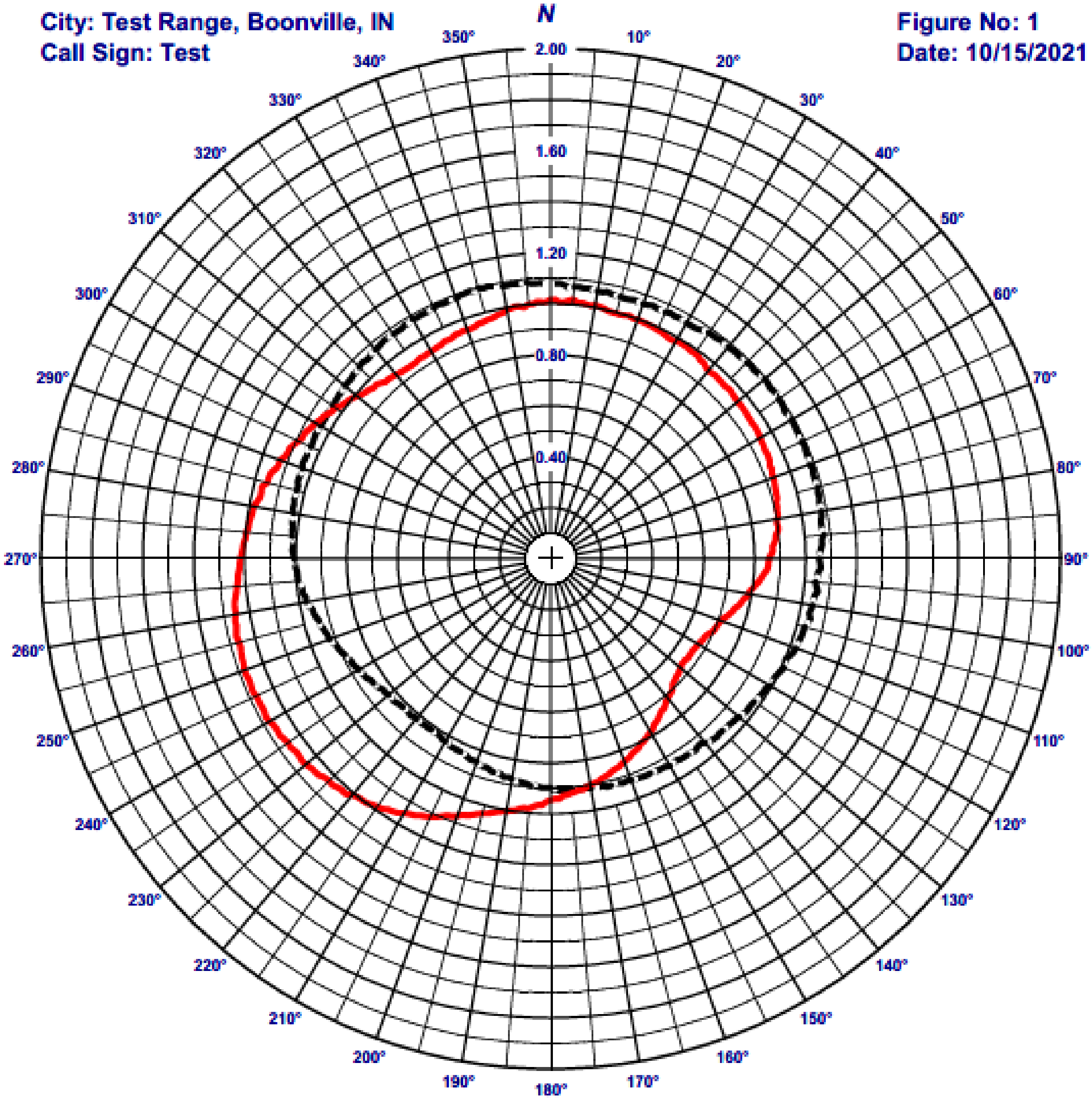
January 19, 2022

ERI® Horizontal Plane Relative Field Pattern

City: Test Range, Boonville, IN
Call Sign: Test

Figure No: 1
Date: 10/15/2021



Frequency: 98.0 MHz
Antenna Type: LPX
Antenna Orientation: 0° True
Antenna Mounting: Custom mount
Tower Type Fiberglass tower

VERTICAL	HORIZONTAL
RMS: 1	RMS: 1
Maximum: 1.1 @ 54°	Maximum: 1.28 @ 246°
Minimum: .818 @ 213°	Minimum: .659 @ 127°

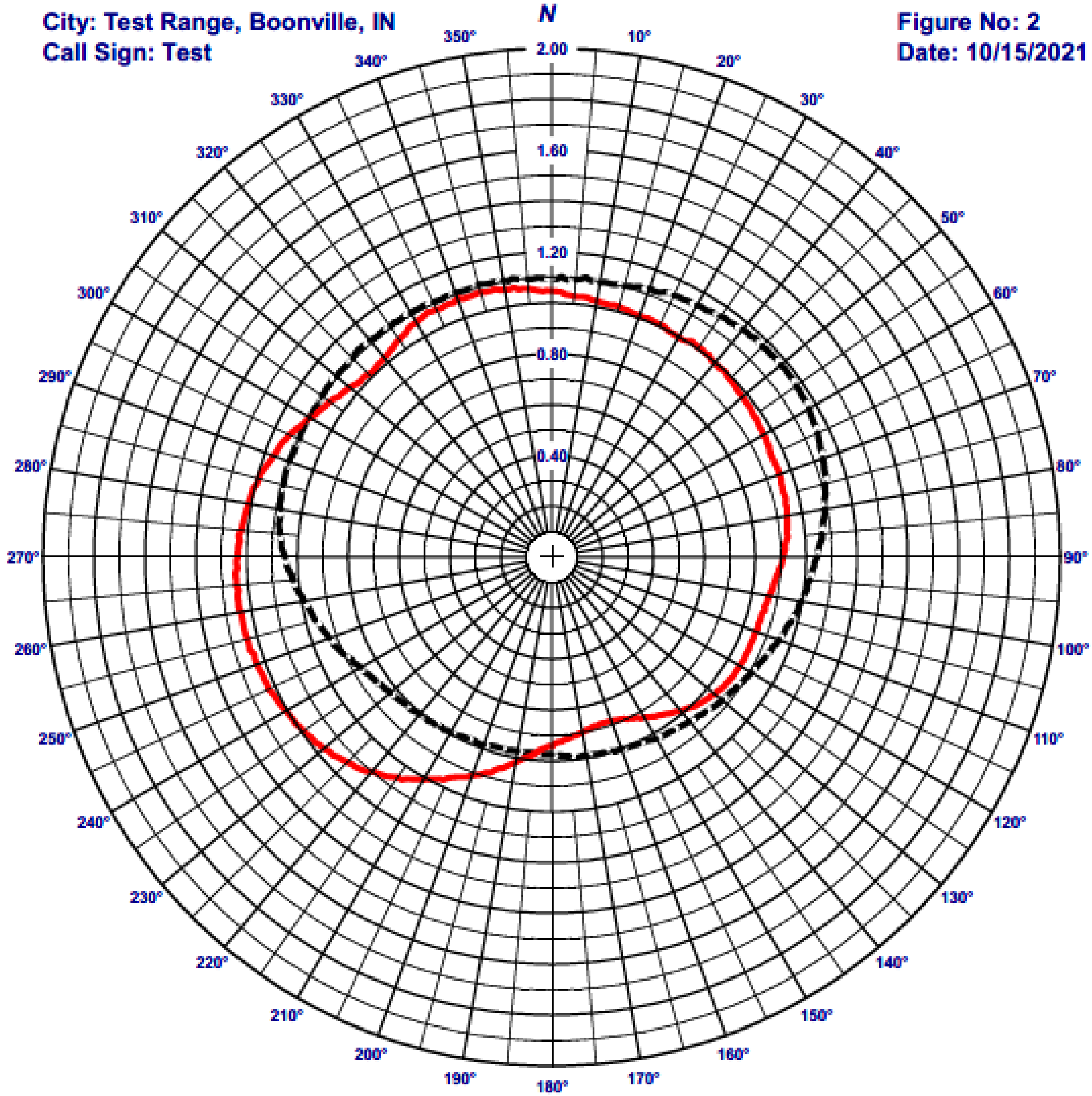
One-bay, 11' Above turntable, centered.

Electronics Research, Inc. 7777 Gardner Rd. Chandler, IN 47610 Phone(812) 925-6000 Fax(812) 925-4030 Web: www.eriinc.com

ERI® Horizontal Plane Relative Field Pattern

City: Test Range, Boonville, IN
Call Sign: Test

Figure No: 2
Date: 10/15/2021



Frequency: 98.0 MHz
Antenna Type: LPX
Antenna Orientation: 0° True
Antenna Mounting: Custom mount
Tower Type Fiberglass tower

VERTICAL	HORIZONTAL
RMS: 1	RMS: 1
Maximum: 1.179 @ 51°	Maximum: 1.246 @ 261°
Minimum: .77 @ 186°	Minimum: .682 @ 163°

One-bay, 11' above turntable, 30" off center.

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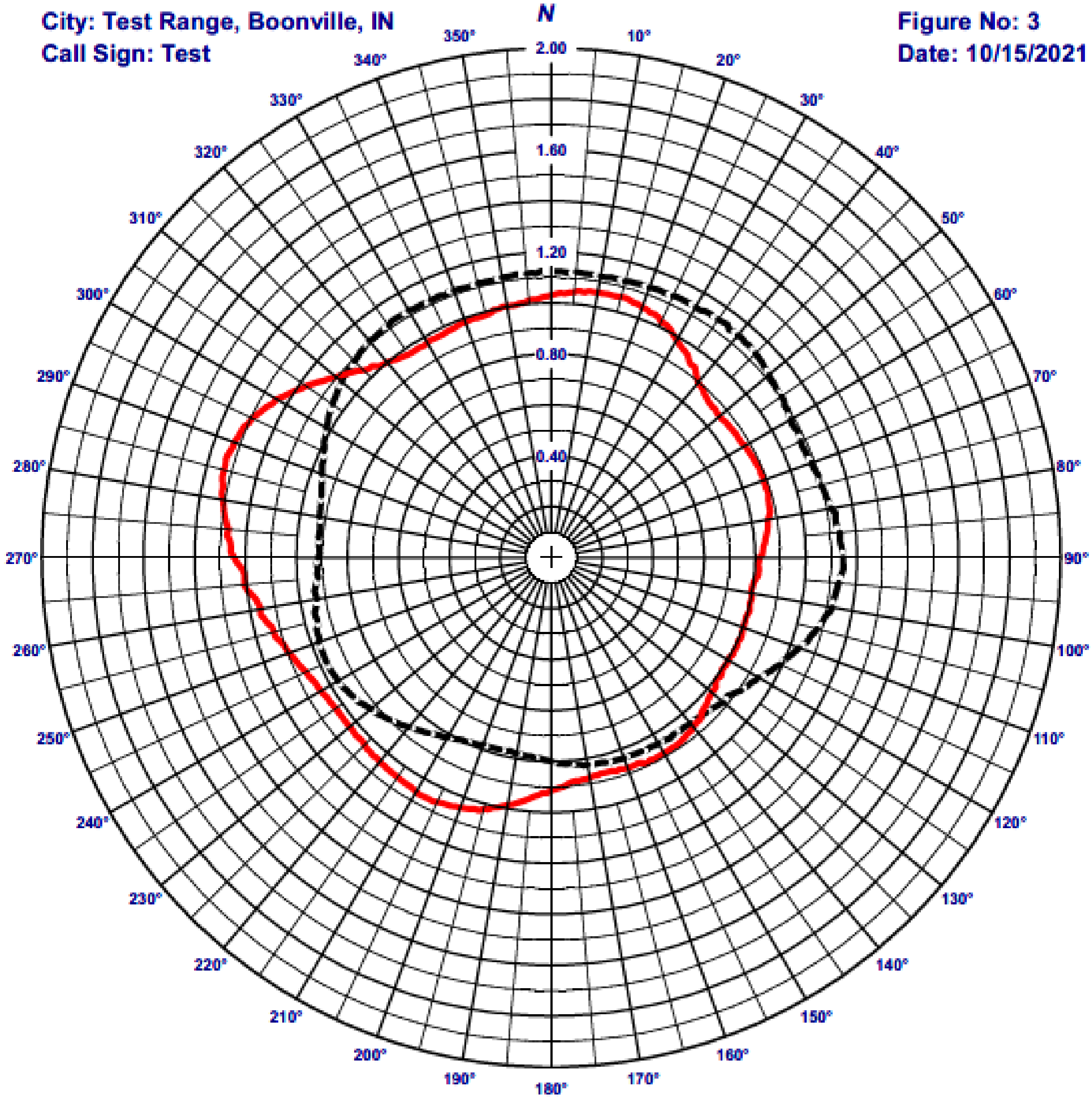
ERI® Horizontal Plane Relative Field Pattern

City: Test Range, Boonville, IN
Call Sign: Test

Figure No: 3
Date: 10/15/2021



Frequency: 98.0 MHz
Antenna Type: LPX
Antenna Orientation: 0° True
Antenna Mounting: Custom mount
Tower Type Fiberglass tower

VERTICAL	HORIZONTAL
RMS: 1	RMS: 1
Maximum: 1.15 @ 92°	Maximum: 1.336 @ 287°
Minimum: .775 @ 192°	Minimum: .798 @ 99°

One-bay, 11' above turntable, 63.5" off center.

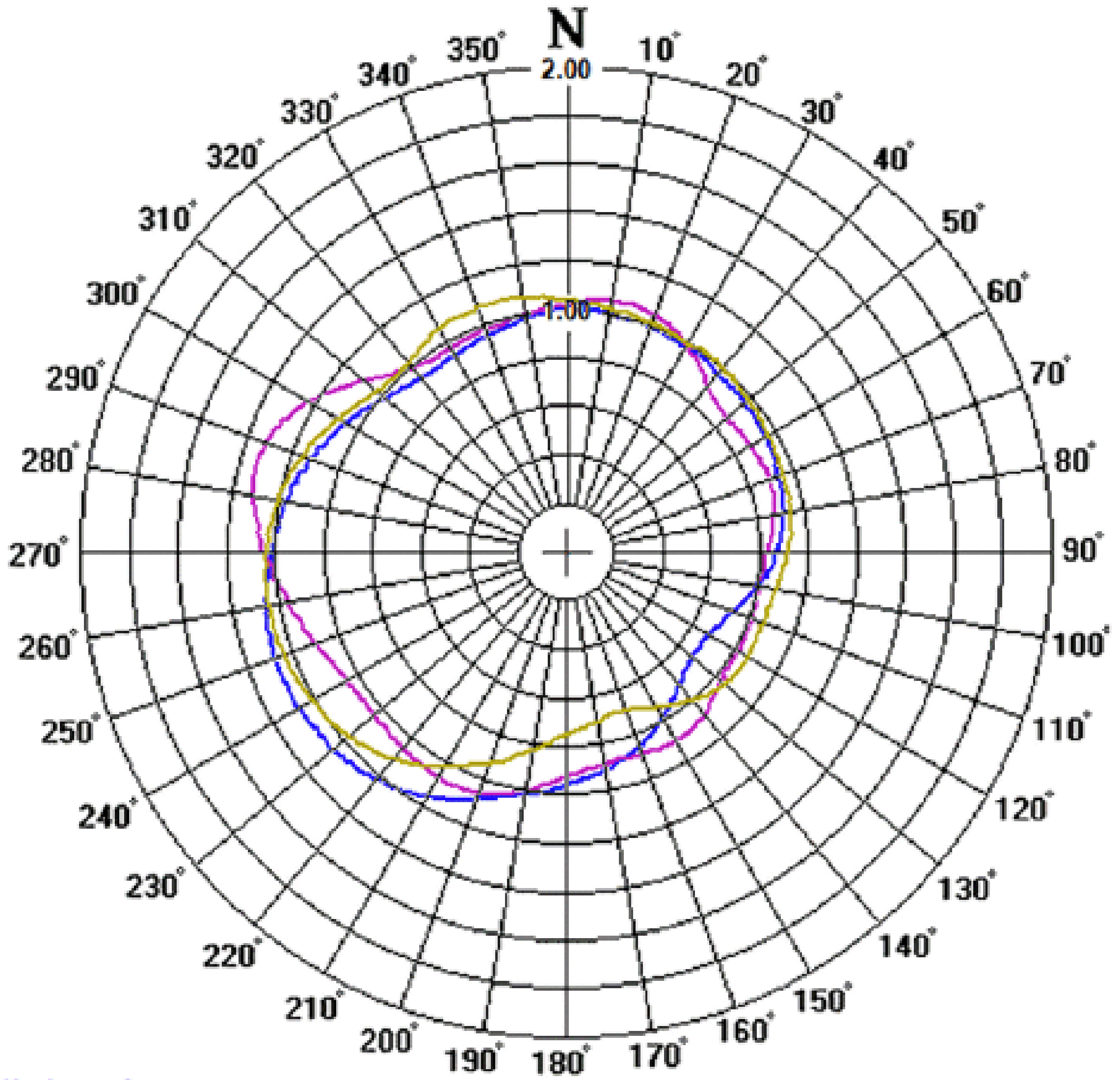
Electronics Research, Inc. 7777 Gardner Rd. Chandler, IN 47610 Phone(812) 925-6000 Fax(812) 925-4030 Web: www.eriinc.com

Range Monitor Antenna 628' Removed from AUT

LPX AUT 11' above and 36" removed from center of turntable

LPX AUT 11' above and 63.5" off center.

Installing LPX AUT



Horizontal
RMS = 1.000

Test #1

One-bay, 11' Above turn table, centered.

Horizontal
RMS=1.000

Test #2

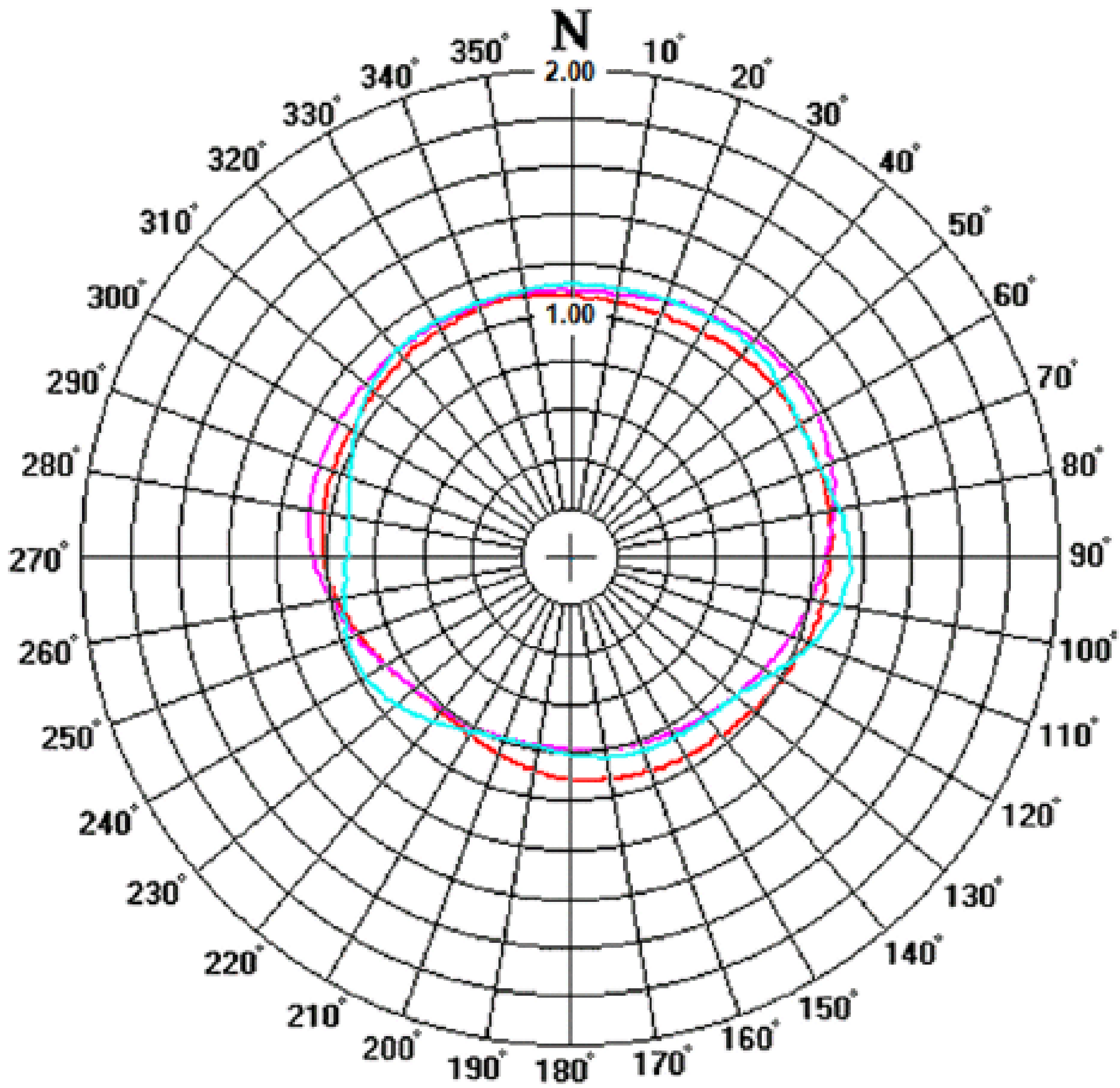
One-bay, 11' Above turn table, 30" off center.

Horizontal
RMS=1.000

Test #3

One-bay, 11' Above turn table, 63.5" off center.

Max Horizontal Change:
2.253 dB @ 178°



Vertical
RMS = 1.000
Test #1
One-bay, 11' Above turn table, centered.

Vertical
RMS=1.000
Test #2
One-bay, 11' Above turn table, 30" off center.

Max Vertical Change:
1.441 dB @ 277°

Vertical
RMS=1.000
Test #3
One-bay, 11' Above turn table, 63.5" off center.

Conclusions

During normal antenna pattern measurements, we supply a test tower to the test site that is mounted with the center of the tower located at the center of the turntable. Then, the antenna is mounted on the tower. Since the antenna moves around the center of the table as the turntable rotates, the ground reflection becomes a vector rather than a scalar. We did a test of the range several years ago using an Andrew low-power UHF slot antenna with one slot per bay level. In this test, we placed the antenna on our turntable with the slot directly over the center of the turntable. This resulted in the ground reflection becoming a scalar or fixed value. The results were submitted to Andrew Corporation. Our range measured patterns of that antenna were identical to the measurements Andrew Corporation made in their Anechoic Chamber. Kerry Cozad, Engineering Manager, Andrew Broadcast Products Business Unit, called me when he saw our range measurement pattern of the Andrew antenna and asked how we could measure the antenna on a ground reflection range and get accuracy equal to that obtained using an Anechoic Chamber. My answer was that there was no range error because the ground reflection didn't change with the rotation of the table. However, if the FM antenna measurement of an antenna mounted on a tower is made, the ground reflection changes because the antenna is not over the center of the turntable.

So, the plan was to verify what that range error is due to the fact that the FM antenna under tests is not located at the center of the turntable. The testing was begun with the center of the FM radiating element directly over the center of the turntable. Then, it was moved away from the center of the table by 30-inches and that measurement was followed with the antenna away from the center of the table by 63.5-inches. The results showed a range error of ±1.13 dB for Horizontal Polarized pattern measurements and ±0.72 dB for Vertical Polarized pattern measurements.

These range error results indicate that directional antennas will have significantly fewer final pattern errors when developed and measured on a horizontal plane antenna test range than if designed using computer modeling only. ERI often uses a computer model as a starting point for the design of directional antennas, but the final results are based on pattern range measurements at our antenna test range located in Boonville, Indiana. ERI has made field pattern measurements of many of our directional antennas and, these measurements have confirmed that the antenna range measurements are accurate.

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January 19, 2022

Appendix B Test for Accuracy of Two Bay FM Antenna Range Measurements Versus Multiple Bay Arrays

The purpose of the tests was to display the effects of using only two bays of a multiple bay FM directional array to predict the results of the performance the same basic array that would have more bays. The tests were performed on the south ERI VHF antenna range.

Pattern measurements were made on a sixty-acre antenna pattern range that is owned and operated by Electronics Research, Inc. The tests were performed under the direction of Thomas B. Silliman, president of Electronics Research, Inc. Mr. Silliman has a Bachelor of Electrical Engineering and a Master of Electrical Engineering degree from Cornell University and is a registered professional engineer in the states of Indiana, Maryland, and Minnesota.

Description of Test Procedure

The test antenna consisted of an ERI model LPX antenna in both a 4-bay and then split into two 2-bay configurations. The antennas were mounted on a support pole which was, in turn, mounted to the face of a 42-inch support tower. All tests were performed on a frequency of 98.9 megahertz.

Measurements were performed with the test antenna placed at on two different 42-inch support towers. The first test which was with a 2-bay antenna only was mounted to a 42-inch face tower designed by Tower Innovations. (Figure No. 7) Later, the 4-bay and the upper and lower 2-bay arrays were mounted on an ERI 42-inch face tower. (Figures 10T, 11T, and 12T).

The support structures were erected vertically on a turntable mounted on a non-metallic building with the antenna centered vertically on the structure, making the center of radiation of the test approximately 30 feet above the ground. The turntable is equipped with a motor drive and a US Digital angle position indicator. The resolution of this angle position indicator is one-hundredth of a degree.

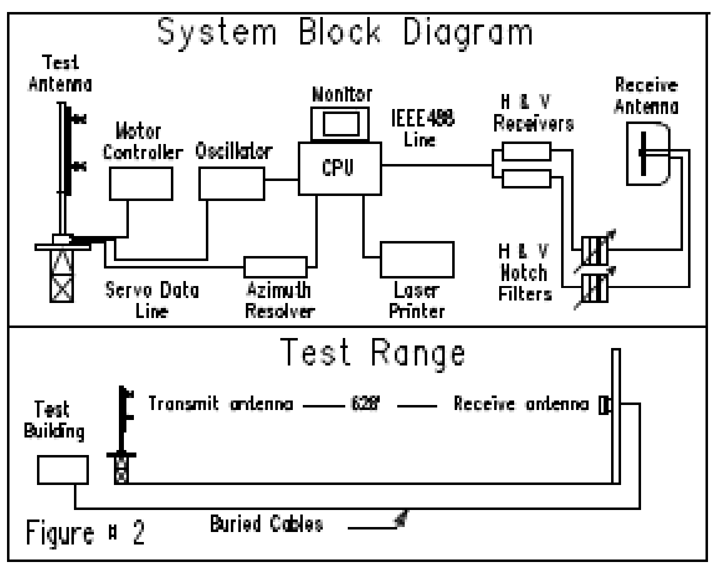

Figure # 2

The antenna under test was operated in the transmitting mode and fed from a HP8657D signal generator. The frequency of the signal source was set at 98.9 MHz and was constantly monitored by a Rohde & Schwarz ESVD measuring receiver.

A broadband horizontal and vertical dipole system, located approximately 628 feet from the test antenna, was used to receive the emitted test signals. The dipole system was mounted at about the same height above terrain as the center of the antenna under test.

The signals received by the dipole system were fed to the test building by way of two buried Heliax cables to the measuring receiver. This data was interfaced to a laserjet printer by means of a computer system. Relative field strength was plotted as a function of azimuth.

The measurements were performed by rotating the test antenna in a counterclockwise direction and plotting the received signal on polar coordinated graph paper in a clockwise direction. Both horizontal and vertical components were recorded separately.

Respectfully submitted,

By: /s/

Dan Dowdle
Test Range Director
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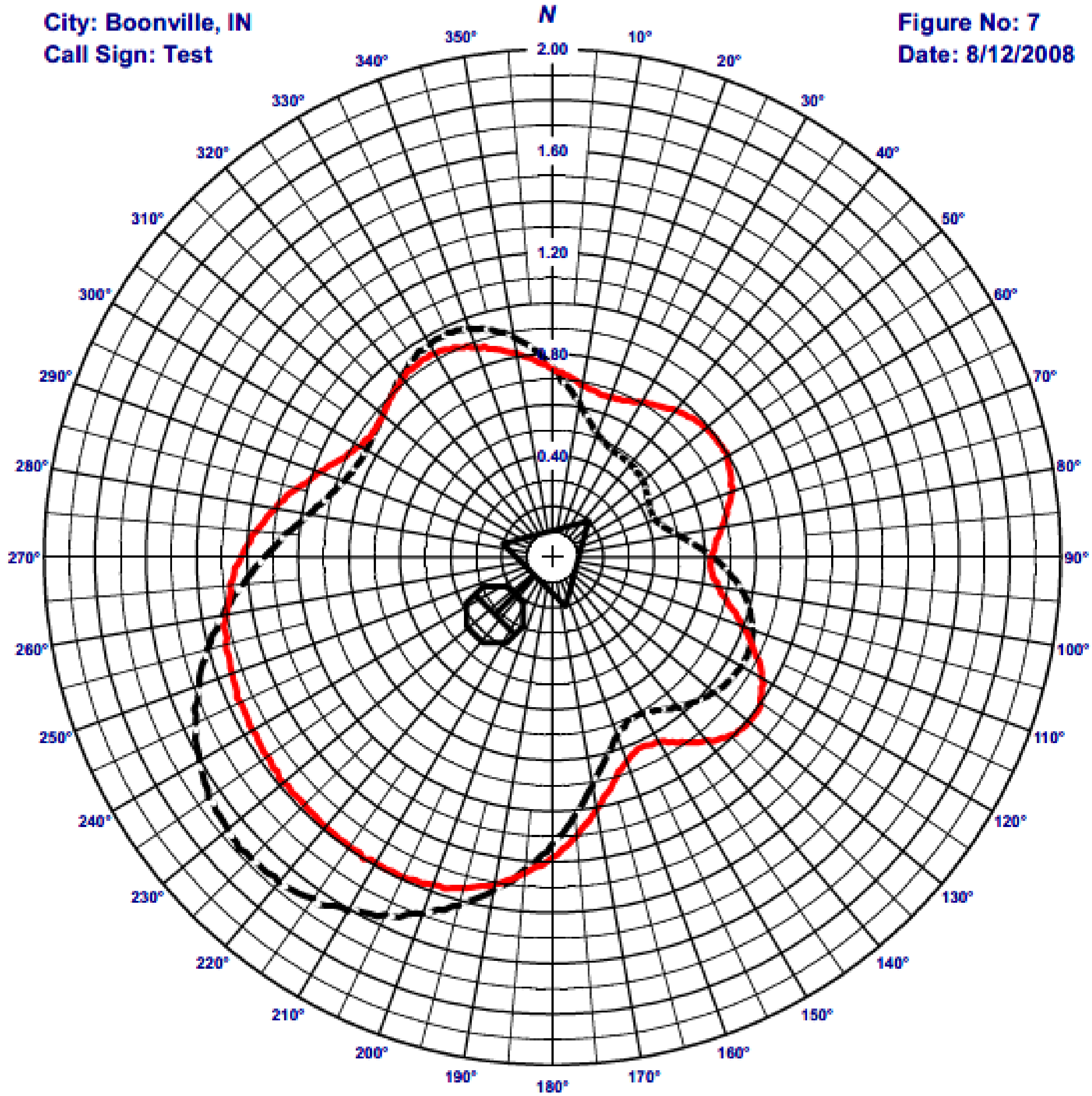
January 19, 2022

ERI® Horizontal Plane Relative Field Pattern

City: Boonville, IN
Call Sign: Test

Figure No: 7
Date: 8/12/2008



Frequency: 98.9 MHz
Antenna Type: LPX-6C-HW
Antenna Orientation: 225° True
Antenna Mounting: 22" ELL
Tower Type 42" Tower Innovations

VERTICAL	HORIZONTAL
RMS: 1	RMS: 1
Maximum: 1.686 @ 227°	Maximum: 1.404 @ 212°
Minimum: .426 @ 67°	Minimum: .622 @ 90°

Two-bay test. The antenna is mounted on the 225° tower face.

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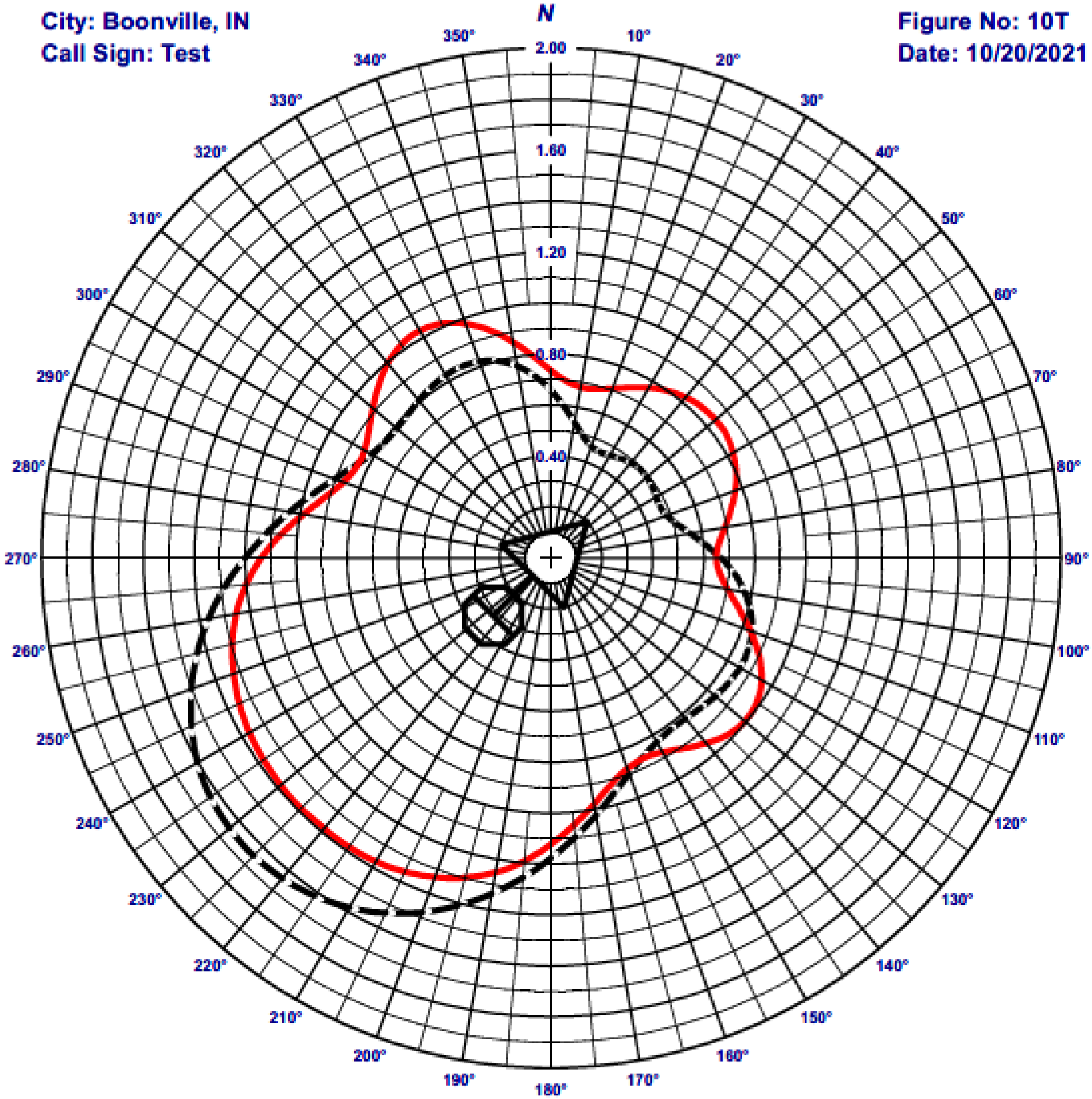
ERI® Horizontal Plane Relative Field Pattern

City: Boonville, IN
Call Sign: Test

Figure No: 10T
Date: 10/20/2021



Frequency: 98.9 MHz
Antenna Type: LPX-4E-HW
Antenna Orientation: 225° True
Antenna Mounting: 22" Ell
Tower Type 42" Lambda

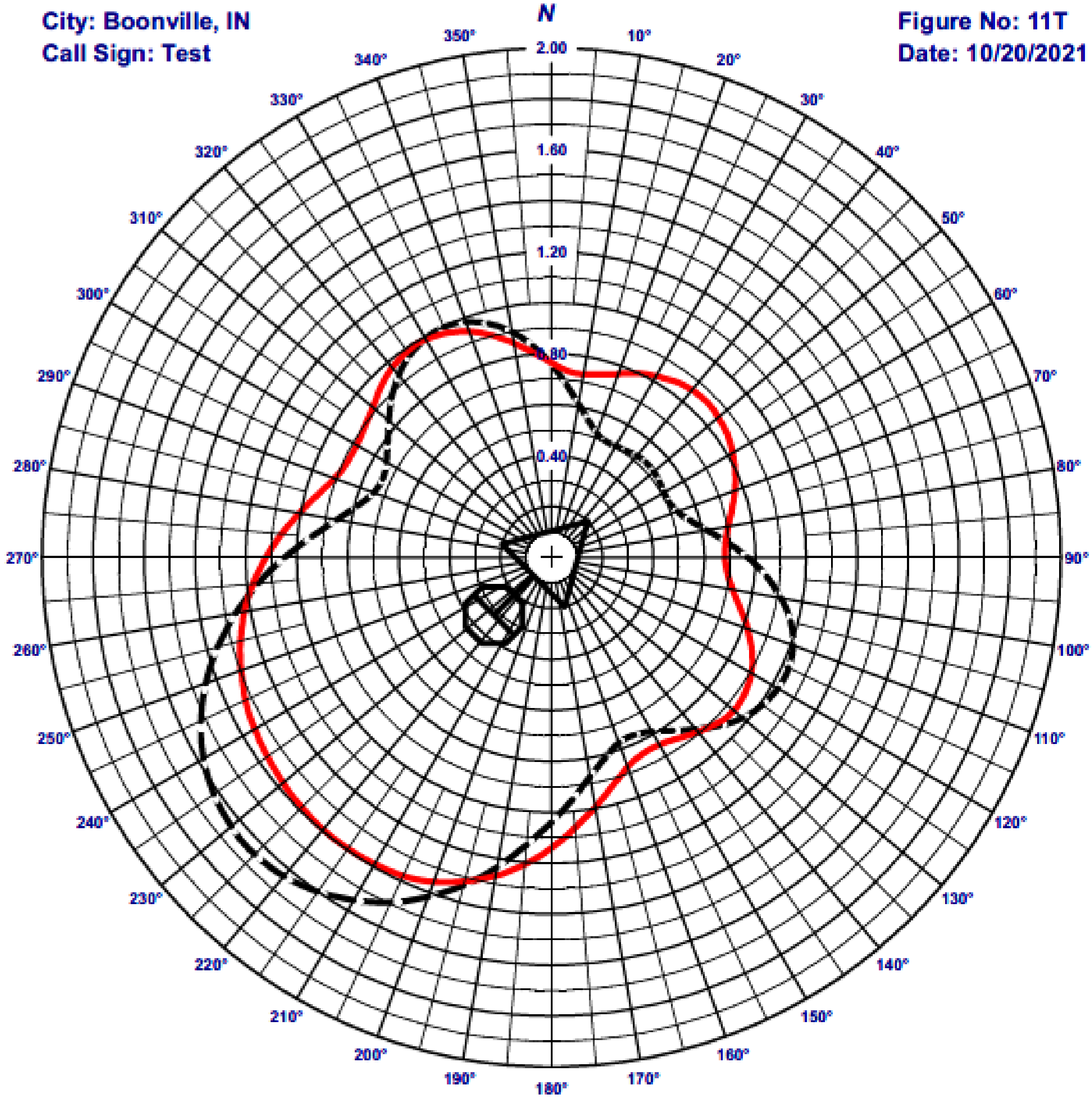
VERTICAL	HORIZONTAL
RMS: 1	RMS: 1
Maximum: 1.651 @ 226°	Maximum: 1.388 @ 226°
Minimum: .458 @ 25°	Minimum: .649 @ 90°

Four-bay test. Face mounted pole. The antenna is mounted on the 225° tower face.

ERI® Horizontal Plane Relative Field Pattern

City: Boonville, IN
Call Sign: Test

Figure No: 11T
Date: 10/20/2021



Frequency: 98.9 MHz
Antenna Type: LPX-2E-HW
Antenna Orientation: 225° True
Antenna Mounting: 22" Ell
Tower Type 42" Lambda

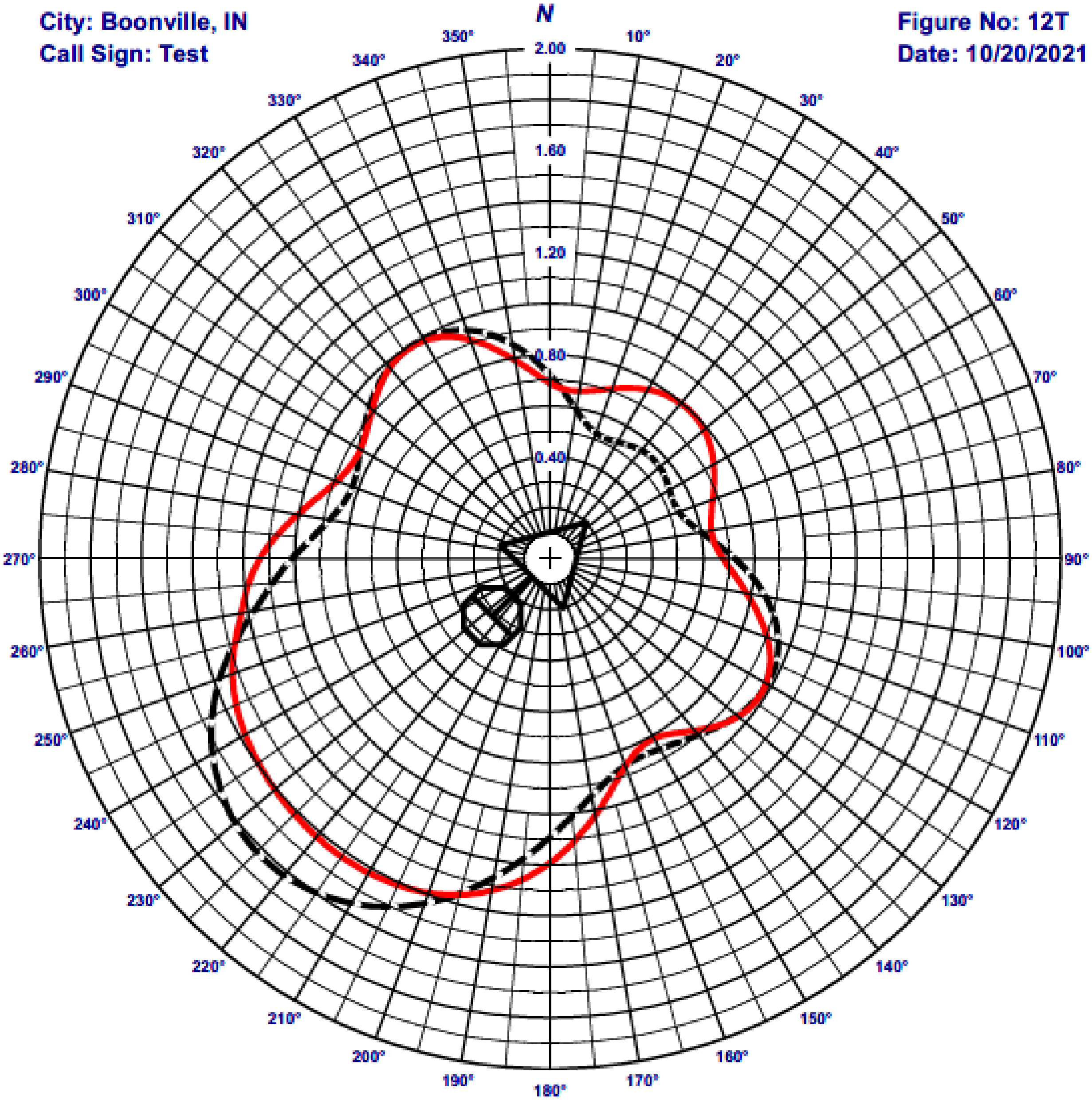
VERTICAL	HORIZONTAL
RMS: 1	RMS: 1
Maximum: 1.649 @ 227°	Maximum: 1.396 @ 218°
Minimum: .503 @ 27°	Minimum: .681 @ 90°

Two-bay test. Face mounted pole. Upper two bays. The antenna is mounted on the 225° tower face.

ERI® Horizontal Plane Relative Field Pattern

City: Boonville, IN
Call Sign: Test

Figure No: 12T
Date: 10/20/2021



Frequency: 98.9 MHz
Antenna Type: LPX-2E-HW
Antenna Orientation: 225° True
Antenna Mounting: 22" Ell
Tower Type 42" Lambda

VERTICAL	HORIZONTAL
RMS: 1	RMS: 1
Maximum: 1.626 @ 223°	Maximum: 1.425 @ 215°
Minimum: .52 @ 24°	Minimum: .641 @ 81°

Two-bay test. Face mounted pole. Lower two bays. The antenna is mounted on the 225° tower face.

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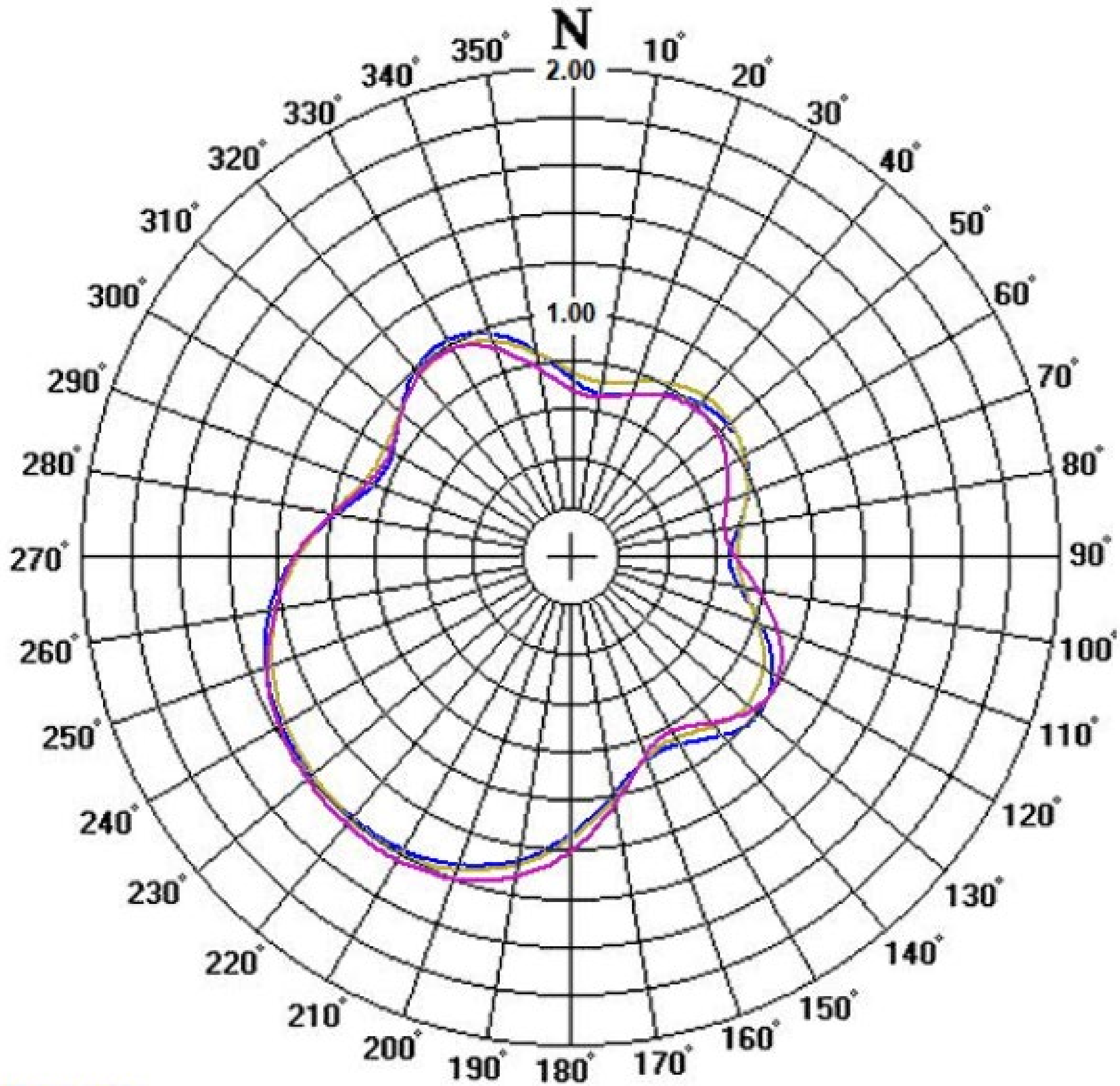
Side view of the 4 bay antenna

Front view of the 4 bay antenna

The 4 bay antenna split into two 2 bay antennas

Range Monitor Antenna 630' Removed from AUT



Horizontal
RMS = 1.000

Test #10T

Four-bay test. Face mounted pole.

Horizontal
RMS = 1.000

Test #11T

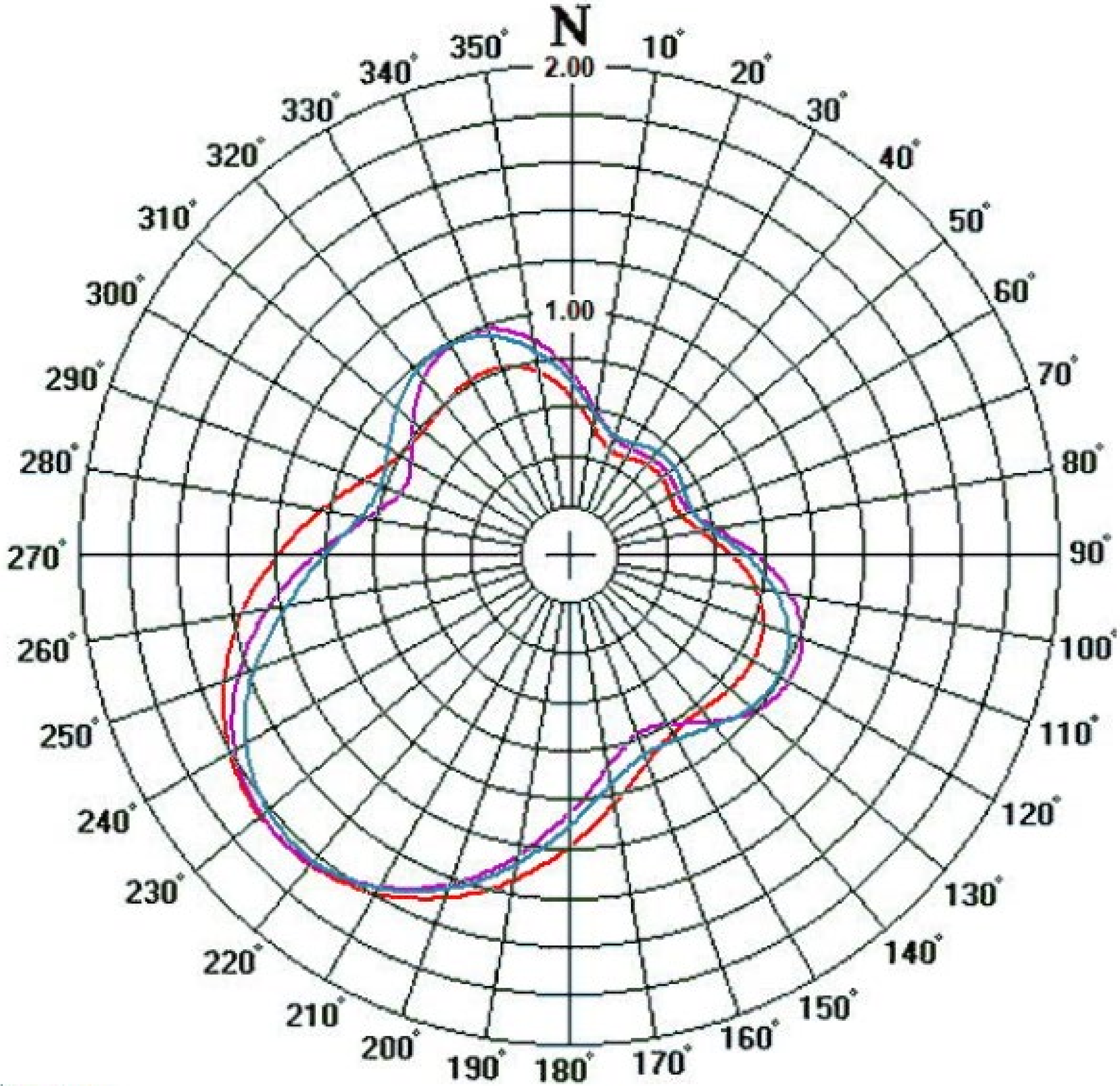
Two-bay test. Face mounted pole. Upper two bays.

Horizontal
RMS = 1.000

Test #12T

Two-bay test. Face mounted pole. Lower two bays.

Max Horizontal Change
1.112 dB @ 69°



Vertical
RMS = 1.000

Test #10T

Four-bay test. Face mounted pole.

Vertical
RMS = 1.000

Test #11T

Two-bay test. Face mounted pole. Upper two bays.

Max Vertical Change
1.800 dB at 285°

Vertical
RMS = 1.000

Test #12T

Two-bay test. Face mounted pole. Lower two bays.

98.9 MHz LPX-6E-HW

The antenna is pole mounted on a 42" face tower.

The leg o.d. used for this drawing is 1 3/4".

The antenna has a standard element with 10" loops.

The antenna is mounted on a 22" ELL bracket.

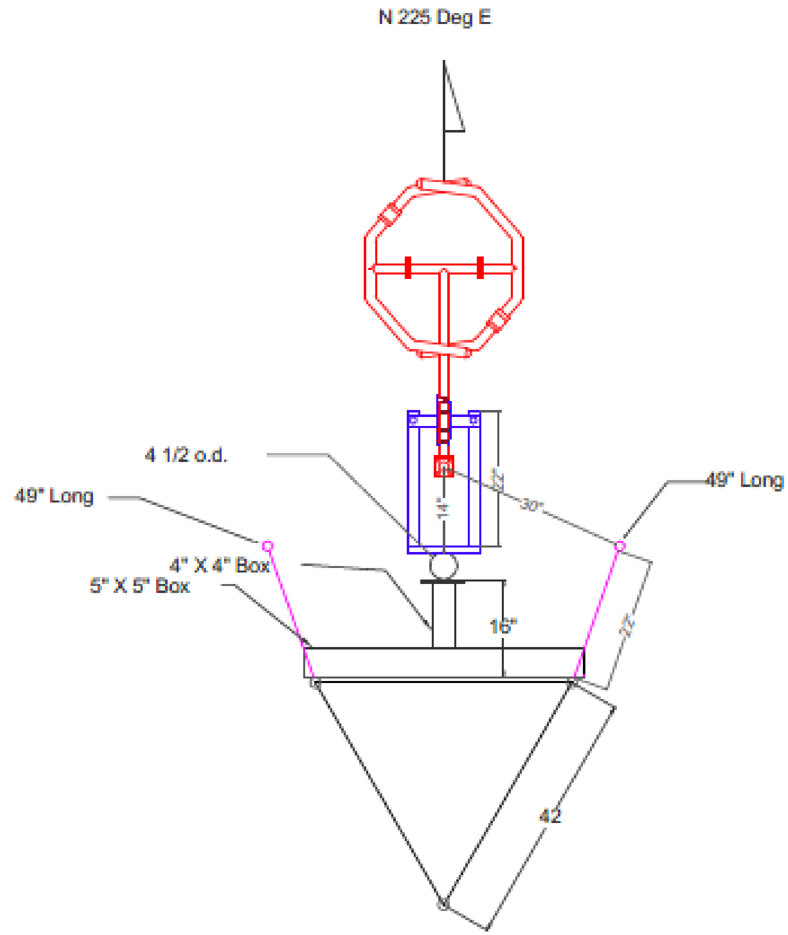
The inter bay line is 14" center line to back of bracket.

The antenna and tower face orientation is N 225° E.

The vertical parasites are mounted on fiberglass.

The vertical parasistes are interleaved between bay pairs.

All dimensions are within +/- 1/8".



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NO	REVISION	APP'D	DATE
6			
5			
4			
3			
2			
1			

NAME

STATION:

FREQUENCY: 98.9 MHz

PATH: G:\DRAFTING\ANTENNA\

FILE: FILENAME | DRAWN: T S | FACTOR: FULL

DATE: 8/13/06 | APP'D: | DWG. NO.

MODEL: LPX-6E-HW

DWG. NO. 1

Conclusions

Electronics Research, Inc. will typically use a two-bay array in tests on our antenna test range for the final design of directional antennas. In order to show that this design procedure is accurate, ERI ran a test where we compared a two-bay antenna range test of a multi-bay antenna to a four-bay antenna range test of a four-bay FM antenna. We made antenna range measurements of the upper two bays of the four-bay antenna, antenna range tests of the lower two bays of the four-bay antenna, and an antenna range test of the full four-bay array. The results of these tests showed that our method of designing directional FM antenna arrays using antenna range tests of only two bays of the directional antenna accurately defines the array's horizontal plane relative field patterns for the horizontally and the vertically polarized radiation.

The test results showed that our antenna measurement accuracy, when only measuring part of a directional FM antenna array, was ±0.56 dB for the horizontally polarized antenna radiation pattern and ±0.9 dB for the vertically polarized antenna radiation pattern.

FM directional antenna arrays are often mounted on towers with other conduits and transmission lines passing through the antenna aperture. ERI's range testing replicates these tower details. Modeling an antenna on a tower with conduit and transmission lines passing through the aperture of the antenna array using a computer model will have significant errors compared to designing and testing the antenna on a ground reflection antenna range.

Respectfully submitted,

By: /s/

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January 19, 2022